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ENVIRONMENTAL IMPLICATIONS OF ALTERNATIVE FUELS

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ABSTRACT

In the past four or five years, EMR has sponsored considerable research into alternative fuels. In addition, we have participated with provincial governments and private industry to demonstrate promising alternative fuels. The thrust of the research, certainly in the very early stages of the energy program, was to find economic substitutes for gasoline and diesel. Thus energy was the key.

Throughout the various efforts, environmental issues were considered only for compliance with existing standards and regulations. That is to say technical efforts did not concentrate on potential environmental improvements that could be realized from alternatives. Now with the softening of oil prices energy considerations are finding an ally in environmental improvements in promoting alternatives.

Emissions from alternative fuels were monitored in most of the R&D and demonstrations. It is the data accummulated throughout the past year on the many programs that are presented. In many instances the approved EPA, Transport Canada or Environment Canada test procedures were not followed. These tests require expensive facilities that were not always available to the particular program. Again, many of the tests were done only to get an idea of the trends in emissions. Reliance upon more precise technical papers published by recognized institutions was used in addressing the emissions effect of programs.

The methanol blend demonstrations in Winnipeg have produced interesting results that indicate some reductions in emissions when compared with the gasoline counterpart vehicle. Also aldehyde testing was carried out on both the blend vehicles and neat methanol vehicles. The results from the blend vehicles indicate that aldehydes are not a problem.

Ontario Research Foundation (ORF) are conducting engine dynamometer tests on five bus engines which will produce comparative emissions data. The engines in question are the standard Detroit Diesel Allison 6V71, an IVECO natural gas engine, an IVECO propane engine, an IVECO diesel engine and a MAN methanol engine. (At time of writing not all of the tests have been completed.)

The mining industry is also concerned with emissions in mines and ORF under contract from CANMET have looked at methanol and methanol/diesel applications to reduce NO_x and particulates in mine applications.

The approach that is followed in this paper is to first give a general overview of the various EMR programs. This is followed by presenting emissions data that have been generated. Finally, an attempt is made to draw conclusions on the potential for emission benefits from alternatives.

RÉSUMÉ

Au cours des quatre ou cinq dernières années, EMR a parrainé un grand nombre de recherches dans le domaine des carburants de remplacement. De plus, il s'est joint aux gouvernements de diverses provinces et à l'industrie privée pour la démonstration de carburants de remplacement prometteurs. L'objet de ces recherches, du moins au cours des stades préliminaires du programme énergétique, était de découvrir des carburants économiques en remplacement de l'essence et du diesel. C'est donc la question de l'énergie qui prédominait.

Au cours des diverses activités on ne s'attardait aux questions environnementales que pour se conformer aux normes et règlements existants. En d'autres mots, les recherches techniques n'étaient pas axées sur les améliorations possibles que pouvaient apporter les carburants de remplacement pour l'environnement. Avec les prix plus bas actuels du pétrole, on peut recourir aux améliorations de l'environnement pour justifier la promotion des carburants de remplacement.

Lors de la plupart des activités de R&D et de démonstration on a mesuré les émissions des carburants de remplacement. Les données qui sont présentées dans le présent rapport sont celles qui ont été recueillies au cours de l'année passée, dans le cadre de nombreux programmes. Dans bien des cas, les procédures d'essai approuvées de Transport Canada ou d'Environnement Canada concernant les normes EPA n'ont pas été suivies. Pour certains programmes particuliers on ne disposait pas des installations voulues, qui sont très coûteuses, pour effectuer les essais. Encore une fois, bon nombre des essais n'ont été effectués que pour avoir une idée de la tendance des émissions. Pour déterminer les répercussions des programmes sur les émissions on s'est fié à des documents techniques plus précis publiés par des institutions reconnues.

Les démonstrations de mélanges contenant du méthanol, à Winnipeg, ont donné des résultats intéressants qui indiquent une certaine réduction des émissions par rapport à l'essence. On a également effectué des essais sur les aldéhydes dans des véhicules alimentés aux mélanges et dans d'autres alimentés au méthanol pur. Les résultats des essais concernant les véhicules alimentés aux mélanges indiquent que les aldéhydes ne posent pas de problème.

L'Ontario Research Foundation (ORF) effectue des essais dynamométriques sur cinq moteurs d'autobus, afin d'obtenir des données comparatives sur les émissions. Les moteurs en question sont le Detroit Diesel Allison 6V71, l'IVECO au gaz naturel, l'IVECO au gaz propane, l'IVECO au diesel et le MAN au méthanol. Au moment de la rédaction du présent rapport on n'avait pas encore achevé tous les essais.

L'industrie minière se penche également sur le problème des émissions dans les mines et l'ORF, sous contrat avec le Centre canadien de la technologie des minéraux et de l'énergie, a examiné les applications du méthanol et des mélanges de méthanol et de diesel, dans l'optique de la réduction du NO_2 et des particules, dans les applications minières.

Dans le présent rapport, nous passerons d'abord en revue les divers programmes d'EMR. Nous présenterons ensuite les données recueillies sur les émissions. Enfin, nous tenterons de tirer des conclusions sur les avantages possibles des carburants de remplacement en terme d'émissions réduites.

INTRODUCTION

Canada reacted to the energy crises of the seventies with an energy policy designed to provide security of supply, self-sufficiency and a fairness in resource distribution. Emphasis was placed on conservation and substitution programs involving research and development, demonstrations and incentive programs.

The recent change in government has not changed the fundamental thrust of energy policy. Recent developments in world wide oil pricing and supply have provided breathing space to conduct energy policy programs in a more stable and rational environment. Also energy programs having lost some urgency and now can help provide for a second government objective; that of job creation and economic stimulation.

The transportation sector is the largest consumer of crude oil based energy. As a result, considerable resources were directed to conservation and substitution programs in the transportation sector. Reseach and development has been shared by several departments including Energy, Mines and Resources, Transport Canada, National Research Council and Environment Canada. The direction and flavour of research was thus influenced by the various departmental mandates. Coordination of the research was controlled to some degree by the committee system established to advise the Energy Research and Development Panel.

The programs that are discussed in this paper are mainly alternative fuel research and development, demonstration and incentive programs managed by the Transportation Energy Division of EMR. As one can imagnine the emphasis in these programs was centered on the production and end use feasibility and viability. Initially little consideration, other than ensuring compliance, was placed upon the potential environmental benefits of alternative fuels.

The situation was different with conventional hydrocarbon fuels where often proposed environmental standard changes could have energy implications. In these cases, R&D was conducted to quantify the energy implications of the proposed changes. Changing fuel specifications such as those forecast for future diesel fuels certainly will require environmental studies.

Emissions from alternative fuels have been evaluated in one form or other in all programs. The problem has been that it has not always been possible, nor desirable, to conduct precise EPA or T.C. Federal Test Procedure emission tests. In many cases, the issues were energy economics and end use technologies that were under investigation, thus rigorous emission tests were not called up. Reliance was placed upon conclusions drawn from technical papers produced by reputable organizations.

A brief outline of the various EMR programs on alternative fuels are given below. This is followed by presentation of the emissions data accumulated or related to the programs. Finally, we attempt to draw some conclusions and make recommendations for future emission work.

The following fuels are addressed:

Propane
Natural Gas
Methanol (Blends and Neat)
Ethanol Blends
Low Cetane Future Diesel Fuel

Reference is not be made to synthetic fuels from natural gas, hydrogen, ammonia and synthetic fuels from biomass and coal. These are considered to be long term alternatives.

PROGRAMS

Propane

Propane, the most common of the alternative fuels, has been used in material handling equipment such as forklifts for many years. This use resulted from the favourable reduction in HC and CO with propane in early spark ignition engines and the need to operate in warehouses. Recent technology advances in emission control systems has negated this environmental advantage.

EMR's major propane conversion programs were the $400 propane vehicle grant and the federal propane vehicle programs. The result of these programs and provincial incentive programs is that the number of vehicles and fueling stations has increased substantially. Table No. 1 gives some details on the propane programs.

Table No. 1 - Propane Penetration in Transporkaion

Vehicle Conversions	
Total to date	130,000
Estimate to 1990	250,000
Fueling Stations	
Total	4,000
% of Fuel Demand	
1986 Level	1.5 - 2.0%
Estimates for 1990	3.0%

The above numbers represent small vehicles such as cars and light trucks. To address the potential for propane substitution in diesel applications, a demonstration was mounted with financial support from the Ontario Ministries of Energy and Transportation & Communications to use propane in urban buses. This demonstration is being conducted by OC Transpo in Ottawa and involves 10 buses equipped with propane engines which are otto cycle conversion of an IVECO 4-stroke diesel engine. This program has both environmental and engine technology ramifications.

Three propane research programs have been funded from the Energy Panel. Two of these managed by the Transport Development Center (TDC) of Transport Canada involve diesel applications. The first was a project to fumigate propane into a IHC industrial diesel. The second was more unique in that it involved a timed injection of a pilot diesel and propane through the same injector housing. The third research program is a joint EMR, Ontario Ministry of Energy and Chrysler Corp. program investigating engine optimization and durability for OEM propane vehicles. This program resulted from an original paper study conducted by Chrysler Canada for TDC.

A fourth program involving propane funded by EMR and Ontario Ministry of Energy involves characterizing six engines commonly used in Urban transport systems. These dynamometer tests are being conducted at Ontario Research Foundation (ORF) and will provide performance and emission data on the following engines:

DDA 6V71 NA	Diesel
IVECO 8220	Diesel
IVECO 8220	LPG
IVECO 8220	Natural Gas
MAN 2566 MVH/200	Diesel
MAN 2566 UH	Methanol

Natural Gas

As with propane, EMR is providing a grant to motorists to convert to natural gas. This grant is $500/vehicle and combined with provincial and industrial incentives is starting to produce results. To stimulate the establishment of a fueling network, a second federal incentive program is available that provides grants of up to $50,000 per station for natural gas refuelling station construction. Table no. 2 illustrates the penetration of natural gas into the transport market.

Table No. 2 - Natural Gas Penetration in Transportation

Vehicle Conversions		
	Total to date	10,000
	Forecast to end of program (Mar '87)	15,000
	CGA estimate for 1990	150,000
Fuelling Stations		
	Total to date	82
	Total to March '87	160
	CGA estimate for 1990	600
% of Fuel Demand		
	1986	0.1% of Road Transport Demand
	CGA Estimate for 1990	1.6% of Road Transport Demand

- Natural gas for vehicles (NGV) although used in several countries in the world is not as advanced as propane applications and has some disadvantages

that require further research. To address this EMR has supported a major R&D program at the B.C. Research Institute in Vancouver that covers most aspects of NGV. The program has five areas of study as follows:

Fundamental Research
Product Evaluation
Product Development
Safety and Regulatory
Information Transfer

Initially the project concentrated on spark ignition engines. Now efforts are being directed towards diesel/natural gas systems. In fact, two separate research contracts were awarded outside of the B.C. Research contract for the design and development of conversion kits for diesel-fuel systems for two and four-stroke diesel engines.

To gather data for further development and to determine the feasibility of natural gas in diesel applications EMR is involved in six demonstrations. The first is a joint EMR Ontario Ministry of Energy and MTC program demonstrating the use of natural gas in bus operations. Six Hamilton Street Railway buses have been retrofitted with otto cycle conversions of a IVECO diesel engines similar to the OC Transpo propane demonstration. The second is a demonstration of 4 Cummins engine converted to dual-fuel with pilot diesel ignition installed in urban class 6 trucks. The third is the conversion of large Cummins engine used in strip mining operation in B.C. The fourth is the demonstration of natural gas in farm operations using a converted John Deere tractor engine. This conversion kit was developed under the R&D contract and is being demonstrated on a Saskatchewan farm. The fifth and sixth demonstrations are in the initial planning stages and will involve a fleet of trucks (class 7 and 8) in B.C. and a fleet of OEM school buses in Quebec.

Methanol Blends

The granting of waivers by EPA to Arco and DuPont for the sale of methanol blends in the USA prompted similar interest in Canada. Automobile manufacturers have expressed concern over driveability, durability and material compatability thus EMR has been involved in blends demonstrations. One was a joint program with Celanese, Ontario Ministry of Energy and MTC; another involved the Manitoba Ministry of Energy, Canadian Methanol Canadien, the MVMA and EMR and was conducted in Winnipeg. Both of these demonstrations used a methanol fuel that matched the proposed Canadian General Standards Boards standard for oxygenated automobile gasoline.

EMR has also drafted a discussion paper on "oxygenated fuel" which has been informally circulated to the industry and provincial governments for comment.

Several companies are presently marketing methanol blends in Canada. Table 3 is a list of these companies showing general location and type of cosolvent being used.

Table No. 3 - Methanol Blend Stations

Company	Location	Blend	No. of Stations
Mohawk	Saskatchewan	5% MEOH + 3% ETOH	30
Mohawk	Alberta	5% MEOH + 3% ETOH	125
Mohawk	B.C.	5% MEOH + 3% ETOH	85
Canadian Methanol Canadien (CMC)-DOMO	Winnipeg	5% MEOH + 3% IBA	3
CMC - Pioneer	Southern Ont.	5% MEOH + 3% IBA	14
AGC - V-Plus	Southern Ont.	4.75% MEOH + 4.75 IBA	15

Methanol Emulsion

Although not strictly a blend, EMR has funded R&D into methanol diesel emulsions. The first project involved NOVA Corp and ORF, and was basically a mechanical emulsion system for use in a Cummins 400 Big Cam engine. The second with Urban Transport Development Corporation (UTDC) and ORF involves a chemically stabilized methanol diesel emulsion. The chemical is a proprietory product of APACE technology of Australia and is looking at performance and emissions from a series of emulsions containing between 5% and 30% methanol. In addition the effects of adding cetane improvers, smoke reducers and water will be determined.

Methanol -Neat

The majority of the federal activity in neat methanol use in spark ignition engines has been carried out by T.C. EMR involvement has been in supporting demonstrations. The first was a 25 vehicle fleet of neat methanol (90% methanol 10% gasoline) M90 demonstration in Winnipeg. This was later reduced to 10 Ford Escort vehicles operated by the Manitoba Telephone System using M85 (85% methanol and 15% hydrocarbon fuels). The second is a unique demonstration of the Ford Flexible Fuel Vehicle. This demonstration funded by EMR, Ontario Ministry of Energy and Ford involves vehicles that can operate on either 100% M85, 100% gasoline or any combination of the two.

The main thrust of neat methanol work has been in the diesel application. Project MILE (Methanol in Large Engines) is a joint government industry program to demonstrate the viability of methanol as a transportation fuel for trucks and buses. The objective of this logistic and technical field trial is to generate the data necessary to give the policy makers a complete understanding of methanol fuel. Table 4 gives a breakdown of project MILE's basic elements.

More basic methanol engine characterization has been carried out for CANMET by ORF on a KHD methanol engine. This particular project is specifically designed to investigate the potential emission improvements that can be realized by using methanol in mining applications.

Table 4 Project MILE

Location	Vehicle Type	Engine Type	No
Winnipeg	Flyer Bus	DDA 6V92TA	2
Medicine Hat	GM Bus	DDA 6V92TA	2
Utica	OBI Bus	DDA 6V92TA	3
Buffalo	OBI Bus	DDA 6V92TA	3
Vancouver	MCI Coach	DDA 6V92TA	2
Vancouver	Kenworth Truck	Caterpillar	2
Calgary*	*	*	2
Toronto*	*	Cummins	*

*Not Firm

Project Elements

Engine Developments
Fleet Operations
Engine Durability
Emissions Characterization
Aldehyde Control
Data Acquisition and Analysis
Fuel and Lubricant Development
Safety System Development
Logistics and Economics

Ethanol

In 1981 under the Conservation and Renewable Energy Demonstration Agreement between EMR and Manitoba, a demonstration on Gasohol (10% Ethanol, 90% gasoline) was conducted. Presently Mohawk is marketing a 10% blend in Manitoba with the ethanol being supplied from a refurbished distillery originally designed to produce potable alcohol for the liquor industry.

The Ford FFV will be tried with ethanol substituting for methanol to determine if the system is flexible enough to utilize ethanol.

A research program funded from Energy Panel funds managed by Agriculture Canada was contracted to ORF. This particular program investigated the use of ethanol in a Perkins tractor engine.

Low Cetane Diesel Fuel

The department of National Defence and EMR have both conducted R&D on the 1990 diesel fuel which is high in aromatics and has a low cetane number. The EMR tests are being done by Esso Research with assistance from Cummins Engine Co.

Emission Data from Alternative Fuels

Propane

In 1983 Environment Canada conducted emission tests on several after-market and factory converted propane vehicles. The Transport Canada Motor Vehicle Safety Test Methods (similar to FTP) were carried out for emission determination using the Urban Dynamometer Driving Schedule (UDDS). Table 5 gives the results for a Chevrolet Impala which was an after-market conversion.

Table No. 5 - Emissions - 1981 Impala - Gasoline and Propane

	UDDS				
Fuel	HC g/mi	CO g/mi	NO_x g/mi	CO_2 g/mi	FE L/100km
Gasoline	0.75	10.0	2.60	490	13.5
Propane	0.87	1.3	3.51	435	17.9
Difference	+16%	-87%	+35%	-11	+32%

Table No. 6 shows the emissions from a factory conversion on a 1981 Ford Granada.

Table No. 6 Emission - 1981 Ford Granada Factory Conversion

Fuel	UDDS				
	HC g/mi	CO g/mi	NO_x g/mi	CO_2 g/mi	FE L/100 Km
Gasoline	0.47	10.9	1.17	425	11.8
Propane	1.35	3.2	4.99	346	14.4
Difference	+ 187%	- 71%	+ 326%	- 18.5%	+ 22%

Table No. 7 is the emission from a dual-fuel Lada. This vehicle was a factory conversion to a dual-fuel system which permitted operations on either fuel.

Table No. 7 Emissions - Dual Fuel Lada

Fuel	UDDS				
	HC g/mi	CO g/mi	NO_x g/mi	CO_2 g/mi	FE L/100 Km
Gasoline *	.75	11.4	1.79	401	11.2
Propane *	1.38	0.2	1.19	335	13.8
Gasoline	0.57	7.7	1.54	408	7.7

* Dual Fuel Vehicle

This test program also looked at the effect of EGR on propane emissions since after-market conversions usually resulted in the EGR system being made inoperable. The summary of the results are as follows:

- HC increases
- CO decrease significantly
- NO_x increases when EGR blanked off
- CO_2 decreases
- Factory conversions are slightly better than after-market
- EGR will reduce NO_x
- Dual Fuel vehicles worsen the results

Propane substitution for diesel fuel will offer some reduction in particulates. Table No. 8 is taken from a report by Esso Petroleum on the road testing of a Cummins NIC engine converted to LPG/Diesel operation.

Table No. 8 13-Mode Test Emission Data - Cummins NTC

		Diesel	LPG Diesel	Canadian Requirements
BSHC	g/BHP-HR	0.28	3.33	16 max
$BSNO_x$	g/BHP-HR	7.38	6.43	
BSCO	g/BHP-HR	2.54	8.40	40 max
BHP	BHP	145.4	145.4	
BSFC	g/BHP-HR	182.60	184.55	

Graph number 1 is preliminary data from the dual-fuel single injection system that illustrates a reduction in smoke as the indicated mean effective pressure increases.

Natural Gas

Table 9 is a summary of natural gas emissions (FTP) for first generation conversion kits.

Table 9 Natural Gas Emissions - Generation II

Vehicle	Kit	CO g/mi	HC g/mi	NO_x g/mi
Ford F250	Mogas	4.69	2.36	2.26
Ford F250	Diversified	5.35	2.24	3.27
Chevrolet S-10	Dual Fuel	0.13	2.54	1.53
Chevrolet S-10	CNG	0.42	2.05	1.2
Dodge 600 es	CNG	2.8	0.61	0.34
1987 Canadian Standards		3.4	0.4	1.0

The emissions from generation one equipment exceeds the proposed 1988 Canadian standards by a fair margin. One of the objectives of the R & D program was to develop a second generation of conversion equipment. CNG fuel system with EMR support have generated such equipment and some typical emissions results are shown in Table No. 10.

Table No. 10 Typical Generation II Emissions

NGV Mode as % of Gasoline Mode

Type	Engine Size	Total HC	CO	NO_x
GM	5.7 L	305%	98%	91%
	5.0 L	93%	96%	82%
	4.1 L	113%	62%	121%
	2.8 L	83%	110%	94%
FORD	5.8 L	188%	34%	100%
	5.0 L	52%	66%	68%
CHRYSLER	5.2 L	33%	107%	106%
	3.7 L	102%	73%	105%

The HC emissions are mainly unburnt methane which is not as reactive as HC from gasoline. Unfortunately emissions data from the natural gas diesel work is not available. We hope to have some information from the ORF dynamometer testing of the IVECO natural gas engine within the next few weeks. Data from the dual-fuel electronic control system will be made available when they becomes available.

Methanol Blends

Graphs 2 to 4 give an indication of the emissions from the M5 blend demonstration in Winnipeg. There is a slight trend showing increased NO_x as the load requirements increase.

In contrast to the Winnipeg fleet trials we have included data that was presented to the EPA by DuPont as part of their waiver applications. Table 11 illustrates the exhaust emission which tend to support the Bank of America claim that methanol blends do reduce exhaust emissions.

Table 11 - Methanol Blends - DuPont Waiver

Exhaust Emission Results

Vehicle	Test Fuel	g/miFTP HC	CO	NOx
1984 Ford	Indolene	0.15	3.3	0.94
Tempo, L-4,	5Me/2.5Alx	0.16	3.1	0.94
2.3L	5Me/2.5Et	0.16	3.1	0.99
	5Me/2.5Px	0.16	2.9	0.93
	5Me/2.5Bx	0.15	2.8	0.95
	5Me/4.2Alx	0.15	3.0	0.94
1982 Plym.	Indolene	0.26	4.1	1.4
Reliant,	5Me/2.5Alx	0.31	3.1	0.4
L-4, 22 L	5Me/2.5Et	0.29	4.1	0.4
	5Me/2.5Px	0.27	3.1	0.4
	5Me/2.5Bx	0.33	4.0	0.4
	5Me/4.2Alx	0.21	2.4	0.3
1979 Chev.	Indolene	0.98	11.8	2.0
Caprice,	5Me/2.5Alx	0.42	4.1	1.6
V-8, 5.7 L	5Me/2.5Et	0.38	2.8	1.6
	5Me/2.5Px	0.42	5.1	1.7
	5Me/2.5Bx	0.48	5.6	1.8
	5Me/4.2Alx	0.52	5.6	1.8

Methanol Emulsions

The program at ORF looking at chemically stable methanol diesel emulsion recordered the emissions using 5 separate steady state points. The results are as shown in tables 12 and 13. It was anticipated that reductions in emission that resulted when combined with a particulate trap would permit the engine to achieve 1991 HDV emission standards. This stemmed from the fact that the particulate type was being changed from soluable to insoluable which would be eliminated by the trap.

Table 12 - Methanol/Diesel Emulsions
1800 RPM/75% Load - Increasing Methanol Content

	#1 Diesel	#1 + 5% MeOH	#1 + 15% MeOH	#1 + 25% MeOH	1990 Diesel
CO, PPM	0.13	0.19	0.32	0.41	1.34
HC, PPM	1.37	1.32	1.42	1.42	0.25
NOx, PPM	26.8	27.8	28.3	25.8	26.4
Soluable, Mg/M^3	0.04	0.06	0.06	0.07	0.04
Insoluable, Mg/M^3	0.05	0.03	0.02	0.02	0.04
Total, Mg/M^3	0.09	0.09	0.08	0.09	0.08

Table 13 - Methanol/Diesel Emulsions
1800 RPM/75% Load - With Cetane Improver

	#1 Diesel	#1 + 15% MeOH	#1 + 15% + 0.1 DII	#2	#2 + 15%	#2 + 15% + 0.1 DII
CO, PPM	0.13	0.32	0.35	0.24	2.56	0.29
HC, PPM	1.37	1.42	1.17	0.99	0.26	1.33
NOx, PPM	26.8	28.3	28.6	26.6	31.8	28
Soluable, Mg/M^3	0.04	0.06	0.06	0.02	0.06	0.05
Insoluable, Mg/M^3	0.05	0.02	0.03	0.04	0.03	0.02
Total, Mg/M^3	0.09	0.08	0.09	0.06	0.09	0.07

Methanol Neat

The use of neat methanol holds the greatest potential for improved air quality as a result of reduced tailpipe emissions. The benefits are significant reduction in ozone as a result of replacing the reactive hydrocarbons in gasoline exhaust with less reactive methanol. A paper presented by R.J. Nichols and J.M. Norbeck of Ford Motor Company at the Air Pollution Control Association in Detroit in June 1985 gives an excellent analysis on the implication for ozone gas air quality from methanol-fueled vehicle emissions.

Aldehyde emissions are much higher from methanol engines than from gasoline. Since aldehydes are not regulated this is one area that requires characterization. The general concensus is that aldehydes can be controlled with oxidizing catalysts.

Aldehyde measurements were made of the exhaust on some of the Winnipeg M5 fleet using the DNPH method. The results were inconclusive and certainly support the claim that aldehydes from blends are no problem, particularly if vehicles are equipped with three way catalysts.

Tables 14 and 15 taken from the Ford paper, give an indication of the emissions and Table 16 are results from an EPA test on both Ford Escorts and VW Rabbits.

Table 14 - Summary of Emissions Data Collected to Date on 1983 Methanol Fueled Vehicles

Fleet	NOx g/mi	CO g/mi	RHC g/mi	HCHO mg/mi	% HCHO
California 1	.61	3.19	.35	54	7.2
California 2	.87	2.76	.42	79	8.8
Canada	.99	4.44	.50	75	7.0

Table 15 - Projected 50K Mileage Emission Factor for 1981 Methanol-fueled Escorts FTP

	NOx g/mi	CO g/mi	RHC g/mi
Methanol Fueled	0.41	6.80	0.48
Gasoline Fueled	0.63	8.80	0.50

Table 16 - Emissions from Methanol as Gasoline Replacement

	FORD Escorts		VW Rabbits	
Fuel	Gasoline	Methanol	Gasoline	Methanol
Catalyst	Factory	Noble Metal	Factory	Noble Metal
HC, g/km	0.23	0.26	0.07	0.24
CO, g/km	2.79	3.75	0.67	0.55
NOx, g/km	0.34	0.25	0.10	0.42
Total Particulate	6	4	7	3
Formaldehyde	0.1	20.5	0.0	6.4
Benzene	4.0	0.1	3.3	0.0
Tolueme	10.7	0.1	5.7	0.0

EPA 460/3-82-004

Methanol in diesel applications as per MILE is just starting to produce emission results. Aldehyde monitoring and control will be an important part of the project to characterize the aldehyde emissions and develop catalysts to reduce aldehyde emission to an acceptable level. Tables 17 and 18 are preliminary results from dynamometer test or various methanol engines.

Table 17 - Neat Methanol

	NOx	CO	HC	Particulates	Adehydes	Formaldehyde
Diesel	9.89	5.57	1.11	Not determined	0.09	.039
Methanol	1.66	1.58	0.76	0.06	0.10	.098

Comparative Emissions 6V92TA diesel and 6V92TA methanol - 13 mode test

Table 18 - Diesel and Methanol Zero-Mile Bus Engine Emissions
(gm./hp.hr)

Pollutant	Typical New Diesel Engines	New M.A.N. Methanol Engine with Catalyst	New General Motors Methanol Engine without Catalyst
Particulate	0.57	0.04	0.17
Oxides of nitrogen	6.25	6.60	2.20
Carbon monoxide	3.22	0.31	-
Total organics	1.61	0.68	1.28
Hydro-carbons	1.51	0.00	-
Methanol	0	0.68	1.13
Aldehydes	0.10	0.00	0.15

Table 19 is from tests on a HDK engine commonly used in mining applications. This is an indirect injection engine. The results show considerable improvements in emissions when methanol is used. An interesting observation that also surfaced in this program was that the reduction in Ames number was not proportional to the reduction in particulates as one might expect. No explanation is as yet given for this occurance and the question mutugenic activity of exhaust emission is a potential area for further study.

Table 19 - Methanol in KHD Engine - Mining Application

	MTU Mining Cycle		Modified MTU Mining Cycle	
	Diesel	Methanol	Diesel	Methanol
Gaseous, PPM				
CO	186	77	199	68
HC	168	34	191	18
NOx	486	367	603	517
NO	435	341	578	458
NO_2	51	26	25	59
Particulate, Mg/M^3				
Insoluable	61	0.5	55	0.6
Soluable	27	1.0	58	1.1
Total	88	1.5	113	1.7

Methanol Engine used noble metal catalytic converter with glow plug ignition.

Neat methanol as diesel and gasoline replacement will also eliminate sulphur, lead and aromatics in exhaust emissions.

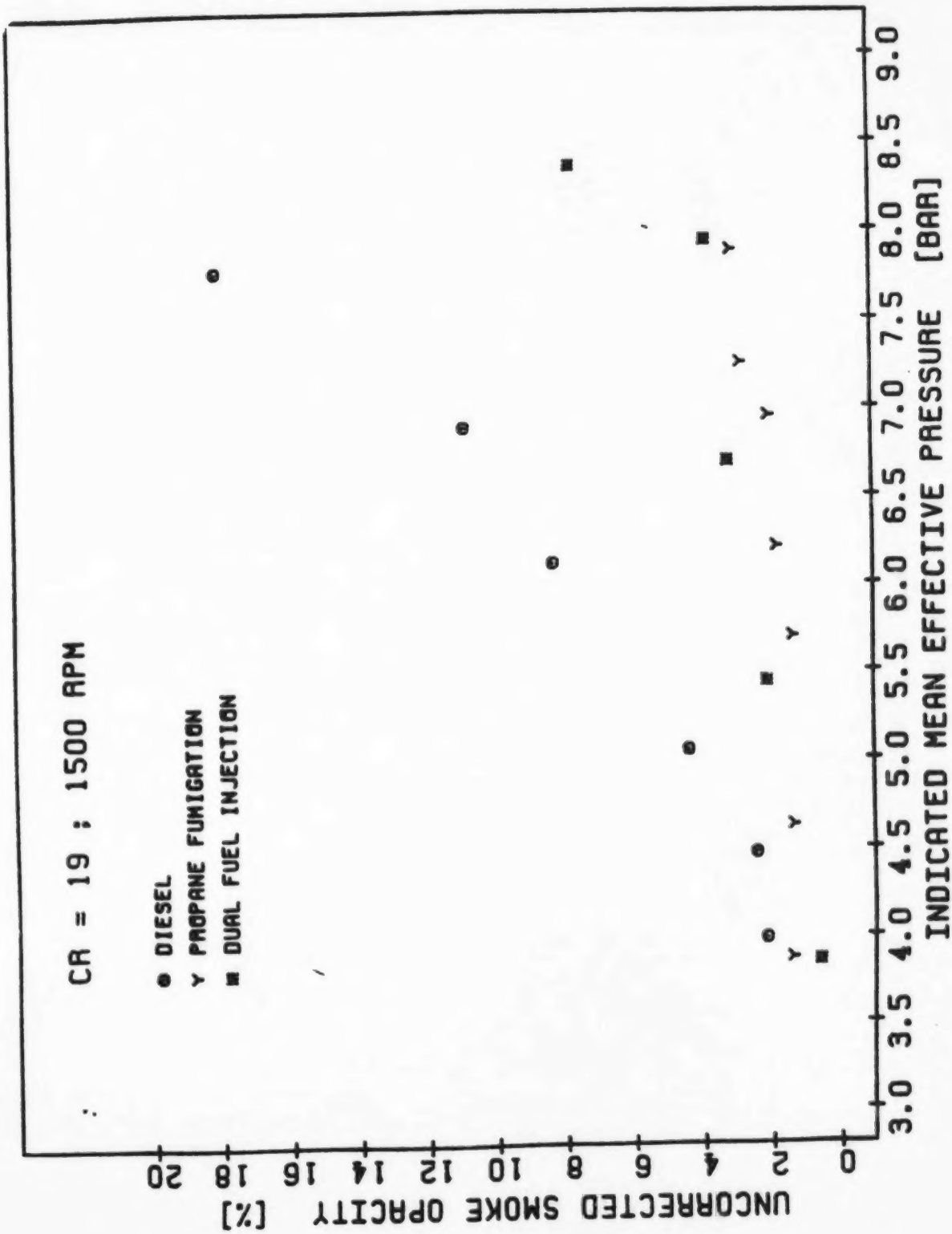
Conclusions

It can be concluded that alternative fuels are not environmental liabilities. In some cases the alternative fuels are preferable over gasolines and diesel. Methanol is a more environmental, acceptable fuel that can contribute to improved air quality. The concern for diesel emissions can only enhance the benefits of substitute's alternatives in diesel applications.

Recommendations

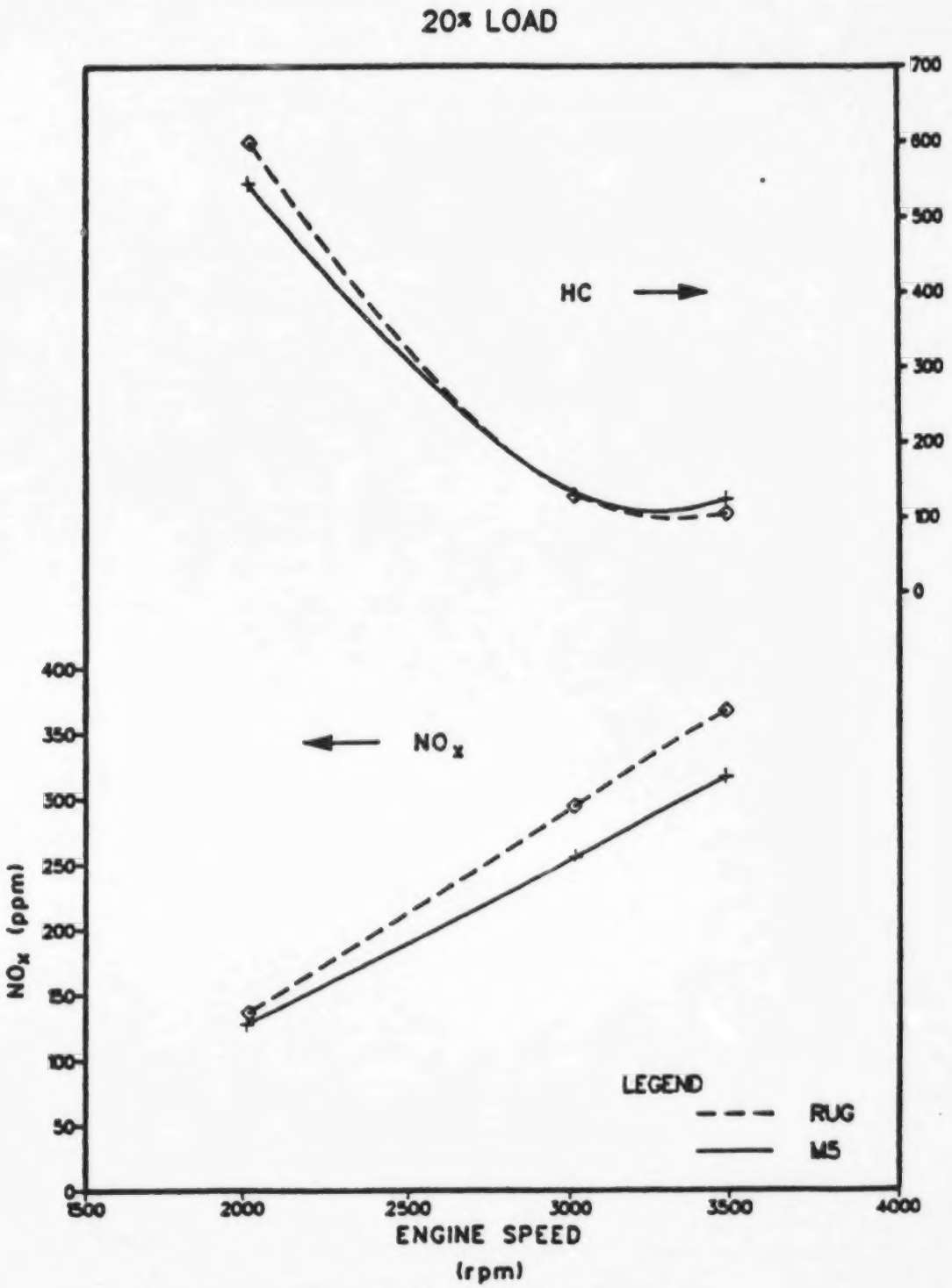
The emissions from gaseous fuels do offer potential for further improvements. The impact of unburnt methane versus gasoline HC emissions should be quantified since the majority of tailpipe HC's from NGV vehicles is in fact methane.

With methanol a need exists to characterize aldehyde emissions and arrive at acceptable limits and mechanisms to control aldehydes to within the acceptable standards.



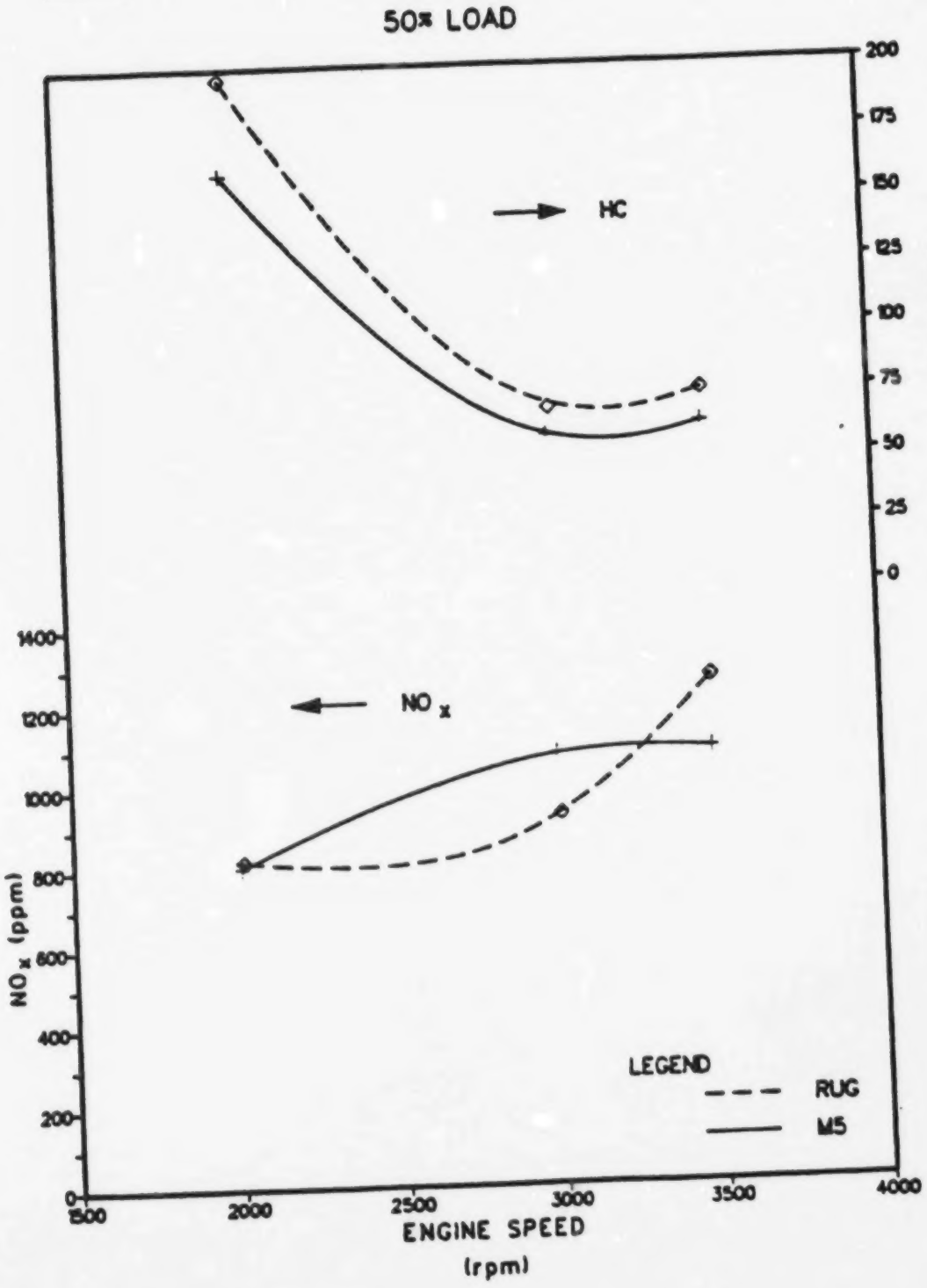
Typical Smoke Emissions

GRAPH 2.

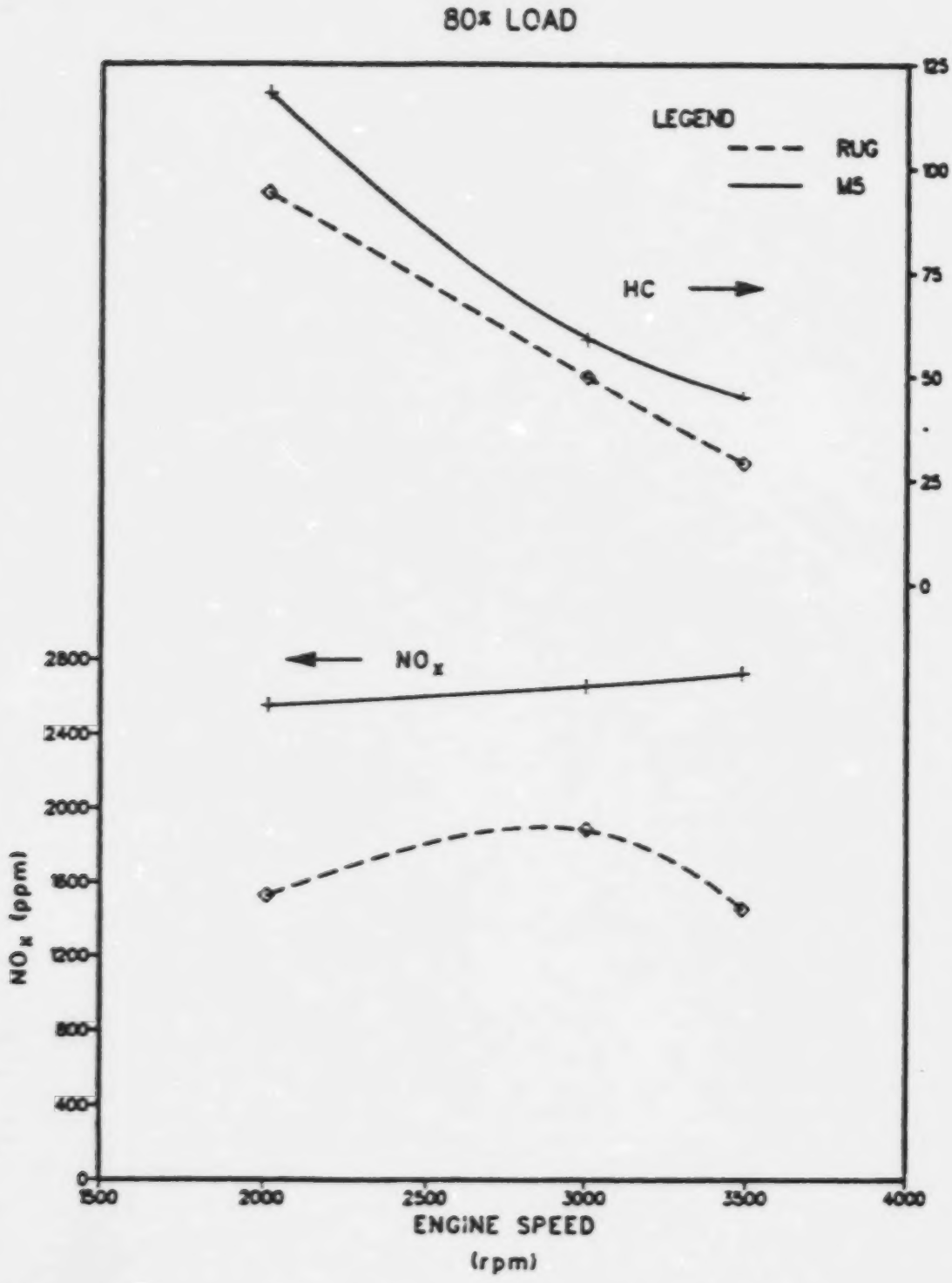


Average HC and NO_x Emissions at 20% Load

GRAPH 3



Average HC and NO_x Emissions at 50% Load



Average HC and NO_x Emissions at 80% Load